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Fire Detection in Aircraft Engine Nacelles

by

C. S. McCamy and Wm. F. Roeser

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for  
Headquarters  
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Wright-Patterson Air Force Base  
Dayton, Ohio  
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# Fire Detection in Aircraft Engine Nacelles

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## 1. Summary

Most of the measurements originally planned on flames of 100/130 gasoline, lubricating oil, and hydraulic fluid burning in air have been completed. The results are being summarized to aid in establishing what additional measurements should be made on these flames. Brief summaries of measurements completed thus far are given herein.

## 2. Measurements of Flame Characteristics Completed

Measurements have been made of (1) the total energy radiated (for wavelengths up to 7 microns), (2) the light emitted, (3) the maximum temperature attained by a No. 18 gage thermocouple, (4) the rate of temperature rise of a thermocouple placed in the flame, (5) the spectral radiation in five selected wave length bands, and (6) the flicker frequency of various natural gas flames and flames from burning liquids. The natural gas flames were stabilized on a burner with an inside diameter of 1-13/16", directed upward. Measurements were made on diffusion flames and flames with premixed air supplied by a blower. Air rates and gas rates were controlled. Lubricating oil, 100/130 gasoline, and hydraulic fluid were burned in an open steel cylinder six inches in diameter and two inches deep with a water cooled bottom. Fresh fluid was introduced at the bottom to maintain a constant level 1/4" below the rim. Measurements were made in still air and in winds with speeds up to 20 m.p.h. Measurements also have been made of the energy radiated by a gasoline fire burning in a shallow concrete pit four feet square.

### 2.1 Average Total Energy Radiated

The average total energy radiated per square centimeter by the flames was measured with a radiation pyrometer with a fused quartz lens. The energy radiated by gas flames ranged from 0.4 watts per square centimeter for a diffusion flame 40 cm in height to 1.5 watts per square centimeter for a blue premixed flame 30 cm in height with an air/fuel ratio of 0.6.

an individual with  
several other persons

44

system of government at all

and the organization of its members

In most cases, according to our sources, the only  
existing form of organization was the brigade, consisting usually  
of one hundred men. The brigade could mean the  
group of 100 or several more, and this was the course of the  
most common organization of resistance forces. Brigades would be  
organized along ethnographic and/or administrative lines.

Administrative units of the brigades: 45

regional groups could be (1) the same two local administrative units  
as the brigades itself and (2) districts. It is quite probable that  
the administrative units of the brigades were formed by the  
units of which it consisted. It is quite understandable to allow such  
units to be used, because each brigade had (3)  
which was enough for the needs of combat and supply. But (4)  
in some cases there were local units, but "districts" organized both  
as brigades and districts. In this case the size of the  
responsible administrative units would naturally be much more extensive  
and the brigades would be large and spread over a wide territory. The  
units were held in control of their respective regions. (5) Cases, the administrative  
units and the brigades of which are separate units, do not fit  
into categories one and II. Cases, which consist of a single  
unit, but divided into several districts or sections or smaller units  
are also seen. And in those of the brigades of which there were administrative  
units just like the new-type units mentioned above.  
Such units are sometimes called a brigade with subordinate units.

Administrative units listed separately: 46

6) brigades under the leadership of a chief, however not  
that would be the only organization of the resistance force.  
There were cases when several men would lead the resistance  
force. In such a unit there would be a chief, who would  
be the main authority, but in other situations perhaps the chief  
of the unit would have no authority at all.

The radiation from the flames of burning liquids ranged from 3.4 watts per square centimeter for the gasoline burning in still air to 7.0 watts per square centimeter for lubricating oil in still air. The flames from gasoline burning in a shallow concrete depression four feet square emitted 11 watts per square centimeter.

## 2.2 Visible Radiation

The light output of the flames was measured with a photronic cell having a spectral response similar to that of the normal eye. The luminous intensities of the gas flames ranged from less than one-tenth candlepower for the blue flames to 67 candlepower for a diffusion flame one meter in height. The luminous intensities of the flames of the liquids ranged from 15 candlepower for the burning lubricating oil to 269 candlepower for a gasoline flame in a wind with a speed of ten miles per hour.

## 2.3 Temperature Measurements with Thermocouples

Measurements were made of the maximum temperature attained by a bare 18 gage chromel-alumel thermocouple when it was placed in the various flames. Temperatures attained in the gas flames ranged from 510°C (950°F) for a 50 cm diffusion flame to 650°C (1202°F) for a 30 cm premixed blue flame. In the case of burning liquids, the thermocouple reached temperatures ranging from 410°C (770°F) for gasoline to 650°C (1202°F) for hydraulic fluid burning in a wind having a speed of twenty miles per hour.

## 2.4 Thermocouple Time Constants

The time required for a bare No. 18 gage chromel-alumel thermocouple to attain 63.2% of its steady state value (usually referred to as the time constant) ranged from six seconds in a gasoline flame in a 20 mile per hour wind to 12 seconds in a gasoline flame with no wind blowing.

The thermocouple time constants in the various natural gas flames studied were between 6 and 7 seconds.

## 2.5 Spectral Radiation

The spectral radiation of the various flames in five selected spectral bands was measured with a recording spectroradiometer.

mejor que el que se obtiene en la parte central de la tierra. La parte central es la que tiene una mayor actividad volcánica y la que más actividad tiene es la que se encuentra en la parte central de la tierra.

### Otra cosa es que

en la parte central de la tierra no se observan las mismas condiciones que en la parte periférica. En la parte central se observan condiciones de actividad volcánica más intensas y más duraderas que en la parte periférica. La actividad volcánica es más intensa en la parte central de la tierra que en la parte periférica. La actividad volcánica es más intensa en la parte central de la tierra que en la parte periférica.

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For the burning liquids, the radiant flux density at a distance of one meter was less than  $10^{-4}$  microwatts per square centimeter in the wavelength band from 230 to 290 millimicrons. In the wavelength range from 300 to 410 millimicrons, the values ranged from less than  $10^{-4}$  microwatts per square centimeter for the hydraulic fluid in still air to 0.23 microwatts per square centimeter at one meter for the same fluid in a 20 mile per hour wind. In the wavelength range from 410 to 550 millimicrons, the radiant flux density ranged from 0.03 microwatts per square centimeter at one meter for hydraulic fluid burning in still air to 14 microwatts per square centimeter at one meter for gasoline burning in a 20 mile per hour wind. In the wavelength range from 550 to 700 millimicrons, the values ranged from 2 microwatts per square centimeter at one meter for lubricating oil burning in still air to 47 microwatts per square centimeter at one meter for hydraulic fluid burning in a 20 mile per hour wind. In the wavelength range from 700 to 2500 millimicrons, the values ranged from 300 microwatts per square centimeter at one meter for gasoline burning in still air to 4400 microwatts per square centimeter at one meter for hydraulic fluid burning in a 20 mile per hour wind.

With the exception of the premixed gas flame 35 cm. in height with an air-fuel ratio of 9.6, which gave a flux density of about  $10^{-2}$  microwatts per square centimeter at one meter in the wavelength range from 230 to 290 millimicrons, the flux densities from the gas flames were within the ranges or less than those observed for the flames of the liquids for the corresponding wavelength bands.

## 2.6 Flame Flicker

Periodic variations in the radiation from the flames studied have been determined from simultaneous records of the radiation emitted in 5 selected wavelength bands, from harmonic analysis of the electrical output of a radiometer, and from high speed motion pictures taken in color and in black and white at speeds up to 1000 frames per second.

The records show that the periodic variations occur simultaneously in all of the wavelength bands. The fundamental flicker frequency of the flames studied ranged from 3 to 18 cycles per second. Winds up to 20 m.p.h. over the surface of the burning liquids only slightly increased the fundamental frequency. In some cases one or more harmonic frequencies were observed.

the same day. The first was a small one, and the second was a large one. The third was a very large one, and it was the largest ever seen. It was about 10 feet long and 5 feet wide. It was made of wood and had a pointed nose. It was very heavy and it took several men to move it. It was used to transport goods from one place to another. It was also used to transport people. It was a very useful tool for the people of the area.

The fourth was a small one, and it was used to transport goods from one place to another. It was also used to transport people. It was a very useful tool for the people of the area.

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### 3. Measurement of Flame Characteristics in Progress

Additional measurements are being made of the electrical conduction by flames of burning liquids and of the rate of increase in the radiation as the rate of combustion increases from the instant of ignition.

### 4. Measurements Anticipated

It is planned to make measurements similar to those given above on premixed flames of different fuel-air ratios from jet burners.

### 5. Financial Condition

Expenditures and commitments on this project:

April 25, 1952 through June 30, 1953	\$20,895.87
July 1, 1953 through September 30, 1953	<u>7,736.49</u>
Total through September 30, 1953	\$28,632.36
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Method of measurement and its discussion. 18

On the basis of the above data and measurements described  
above, it is clear that the two methods outlined for measuring column  
heights in different media can be used only in certain cases.  
The method of measurement by the use of a vertical column  
is not suitable for use in water.

#### Instrumental measurements.

The use of vertical columns for column height measurements  
and the use of horizontal tubes for column height measurements  
are not suitable for use in water.

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Measuring column height by the use of a vertical column  
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